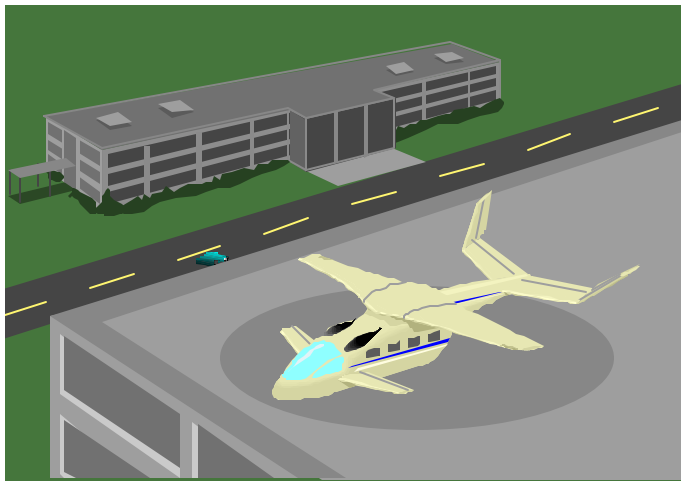
Dr. Henry McDonald
Director
NASA Ames Research Center

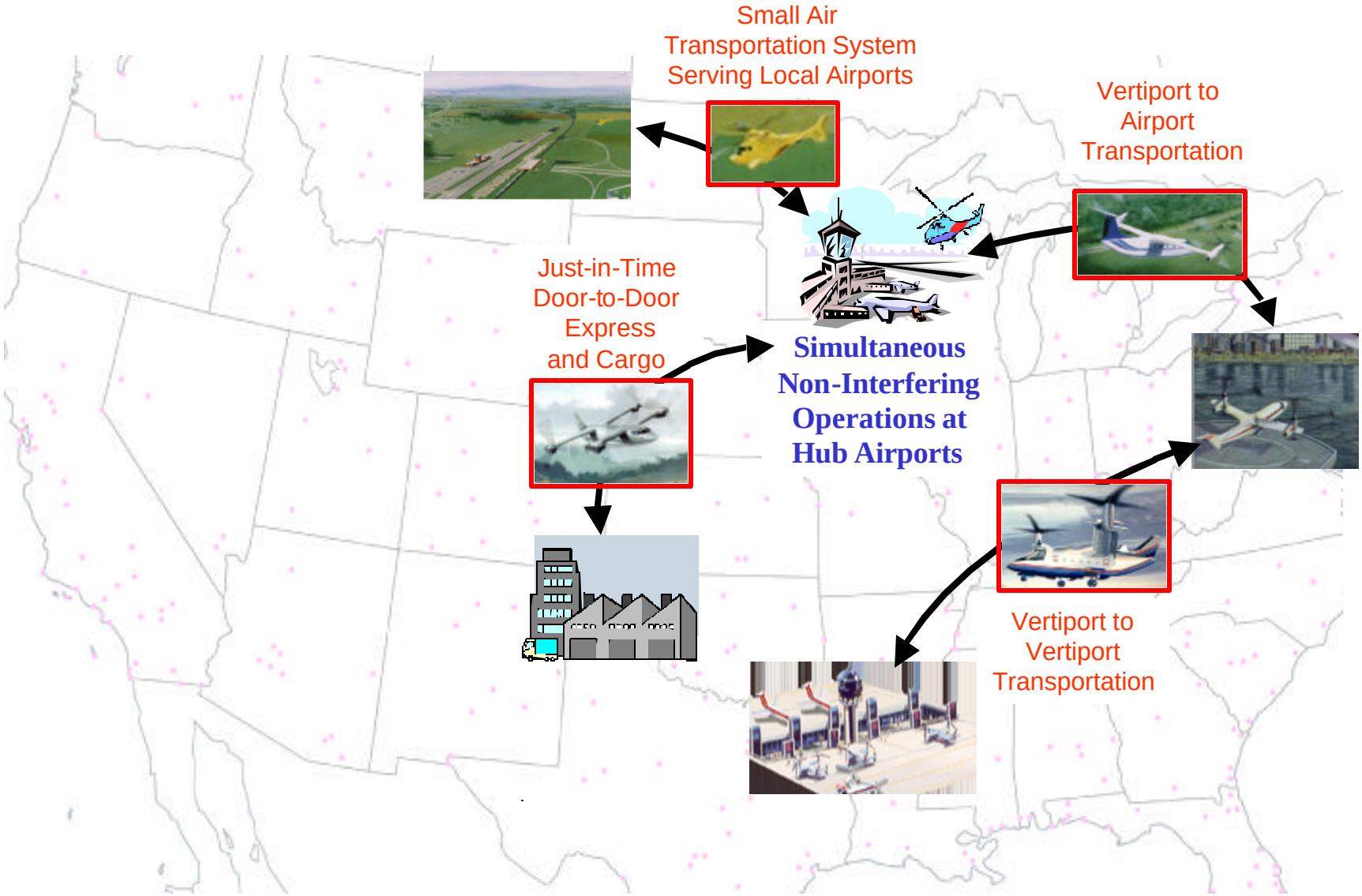
Rotorcraft Vision

True point-to-point or door-to-door transport

- ✓ *Complete flexibility of origin and destination*
- ✓ *No need for extensive real estate or large infrastructure investment*
- ✓ *No constraints on system throughput dictated by the need for runways*



3-D Grid Transportation System



Runway Independent Aircraft Operations

Increases airport throughput by 25% and reduces delays at airports

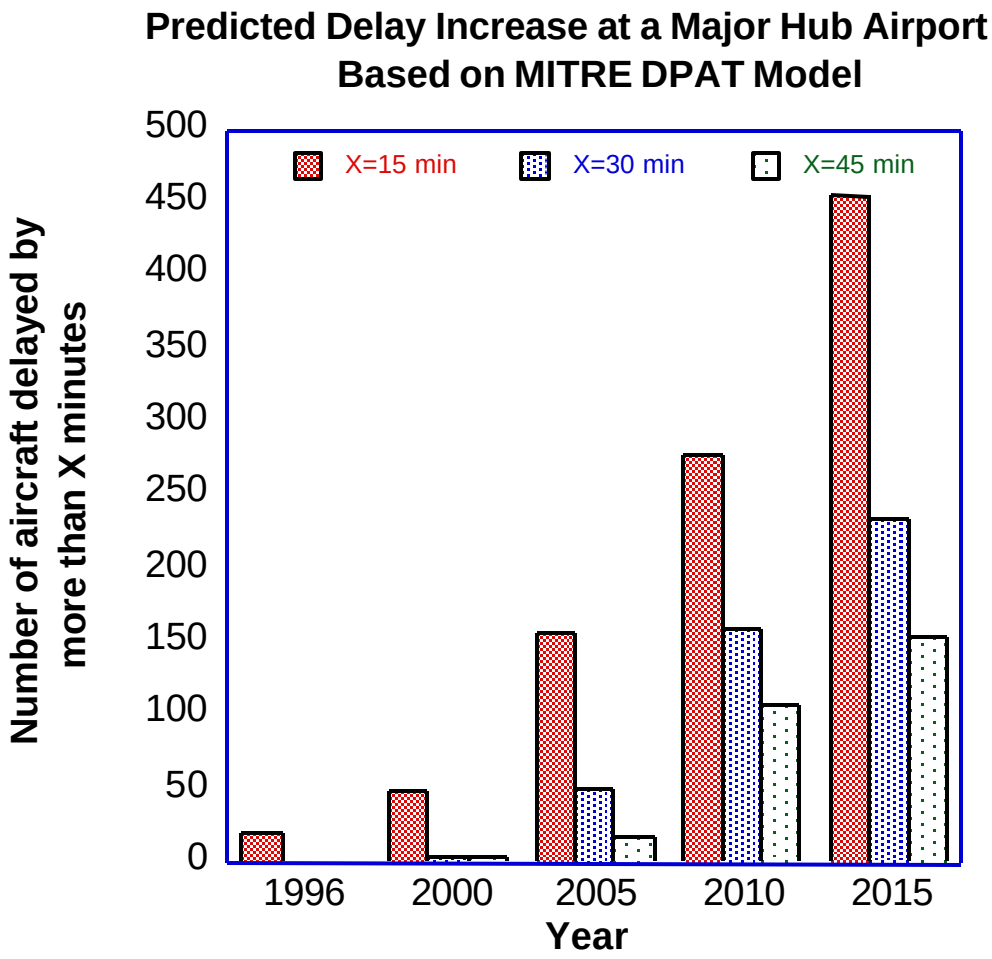
- **Provides 50% as much delay reduction as a new runway**

Improves terminal area airspace safety and reliability

- **Separate corridors and runway traffic for slower aircraft and jet transports**
- **Improved separation in departure corridors**

Commuter fixed wing aircraft (< 300 nm) carry 20% of the passengers, yet account for 40% of the departures at major hub airports

Flight Delays Will Worsen Without Corrective Action



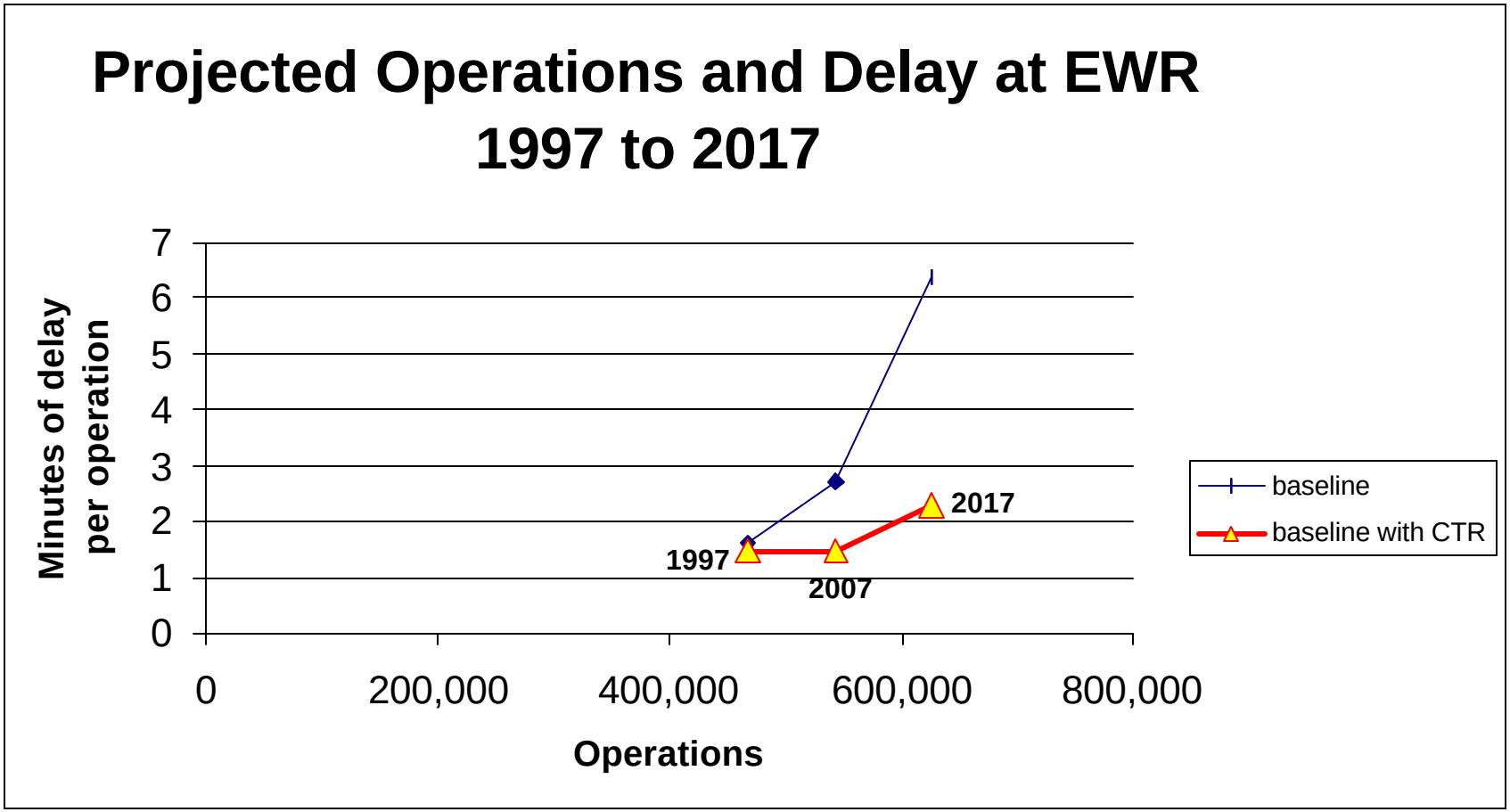
Single day, good weather

Single airport, major hub

Total landings
1996: 997
2000: 1,378
2005: 1,576
2010 1,776
2015: 1,910

Source: Donohue, G., "Investing in Air Transportation Research," *Aerospace America*, Sept. 2000, pp. 28-31

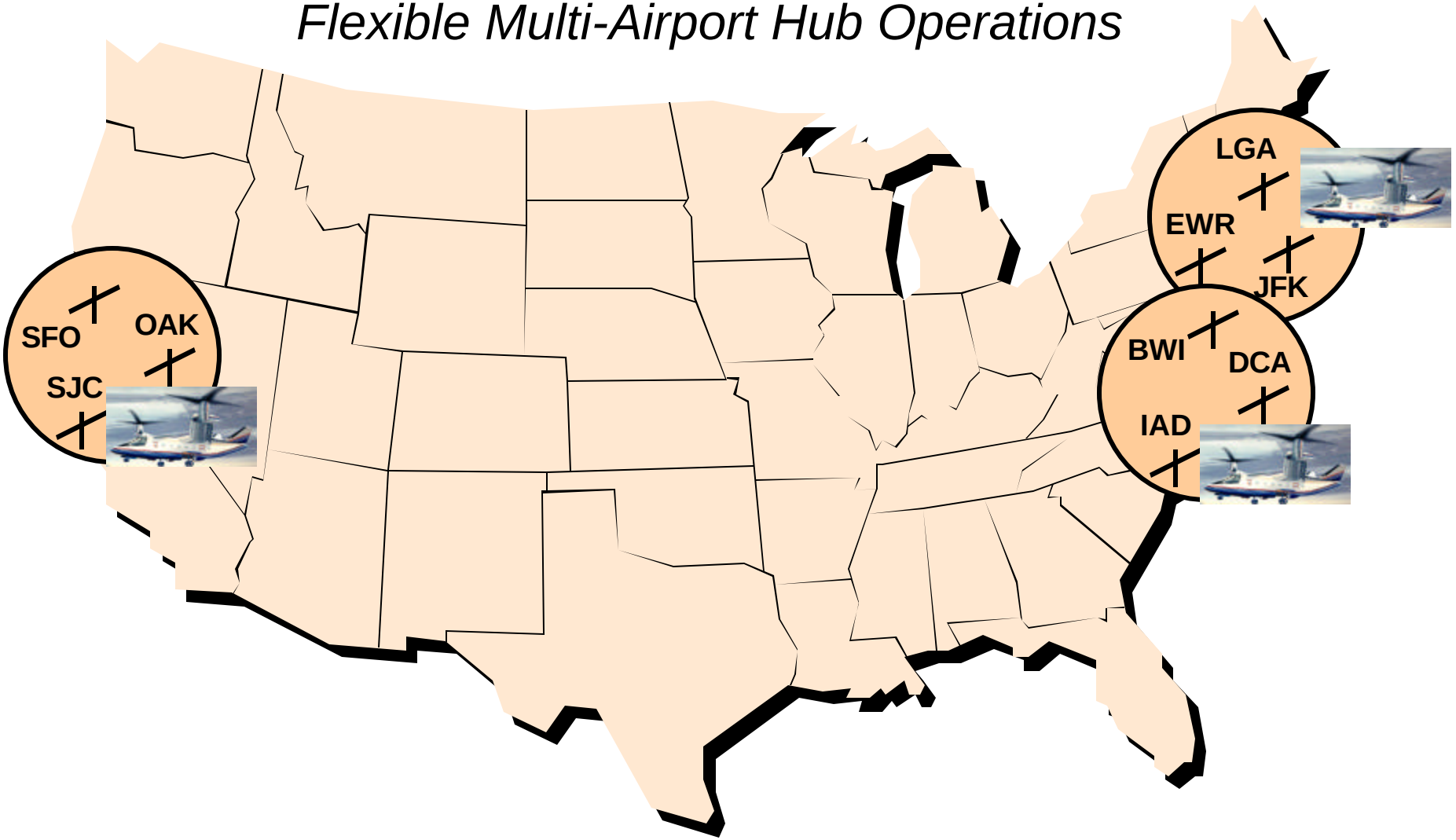
Impact of Runway Independent Operations



Source: Civil Tiltrotor (CTR) Feasibility Study - Impact at EWR

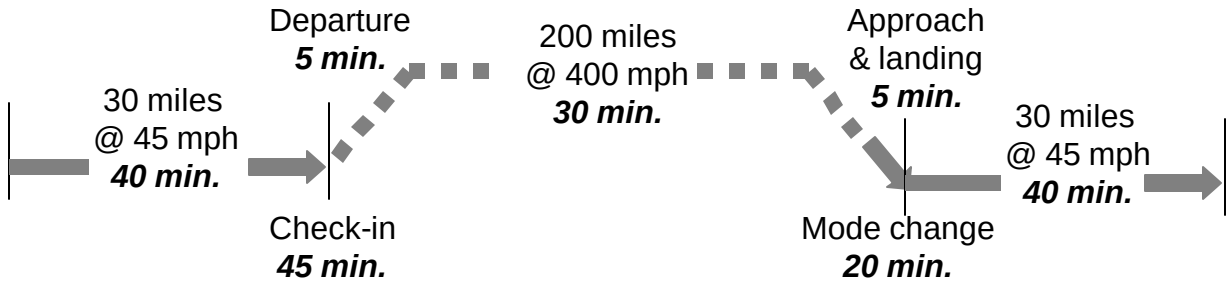
Virtual Hub Concept

Runway-Independent Aircraft Enable
Flexible Multi-Airport Hub Operations



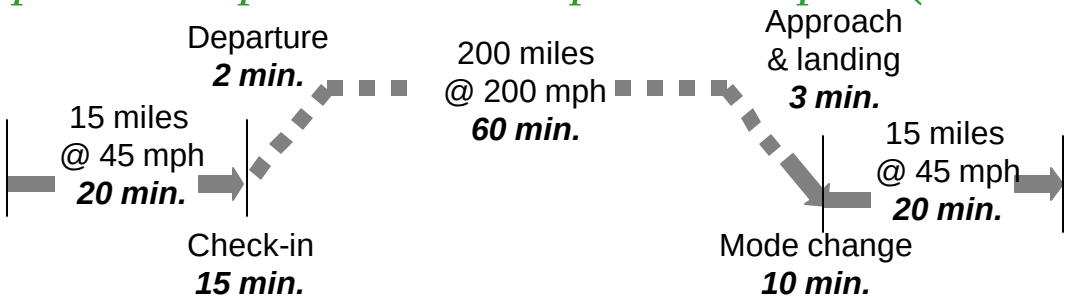
Rotorcraft Can Sharply Reduce Door-to-Door Time

Airport to Airport (Fixed Wing)



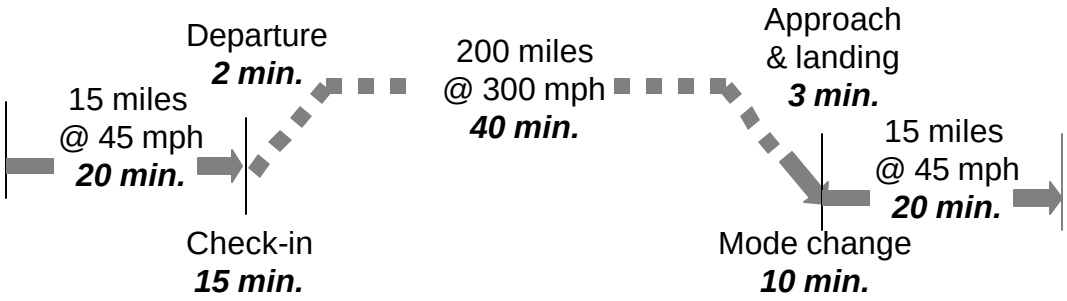
Total trip time
200 miles: 185 min.
300 miles: 200 min.
+ Delay

GA Airport/Vertiport to GA Airport/Vertiport (Helicopter)



Total trip time
200 miles: 130 min.
300 miles: 160 min.

GA Airport/Vertiport to GA Airport/Vertiport (Tiltrotor)



Total trip time
200 miles: 110 min.
300 miles: 130 min.

Barriers to Achieving the Vision

Key Inhibitors to Expanded Rotorcraft Applications:

- Cost per Seat-Mile or Ton-Mile
- Community Acceptance
- Reliable All-Weather Service
- Perceived Safety
- Passenger Acceptance (Ride Comfort, Speed, etc.)
- Piloting Skill Required
- Infrastructure for 3-D Grid Operation

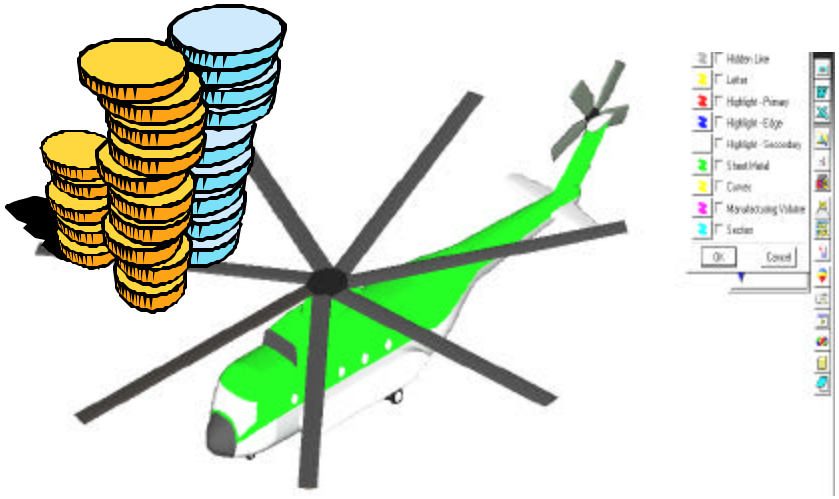
Effects of Technology Improvement

U.S. Army Future Transport Rotorcraft
20-ton Payload, 300-mile Mission Radius

1994

Gross Weight: **126 tons**

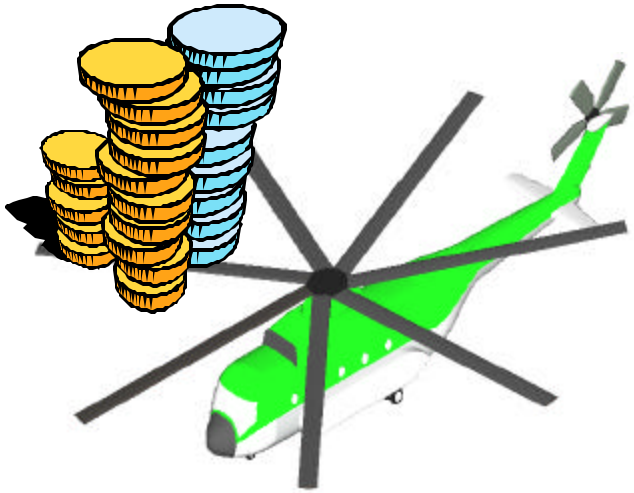
Unit Flyaway Cost: **$186 mil.**

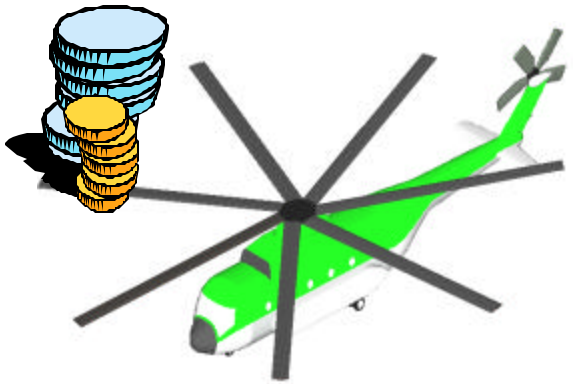


Effects of Technology Improvement

U.S. Army Future Transport Rotorcraft
20-ton Payload, 300-mile Mission Radius

	1994	**2005**
Gross Weight:	**126 tons**	**62 tons (-51%)**
Unit Flyaway Cost:	**$186 mil.**	**$74 mil. (-61%)**



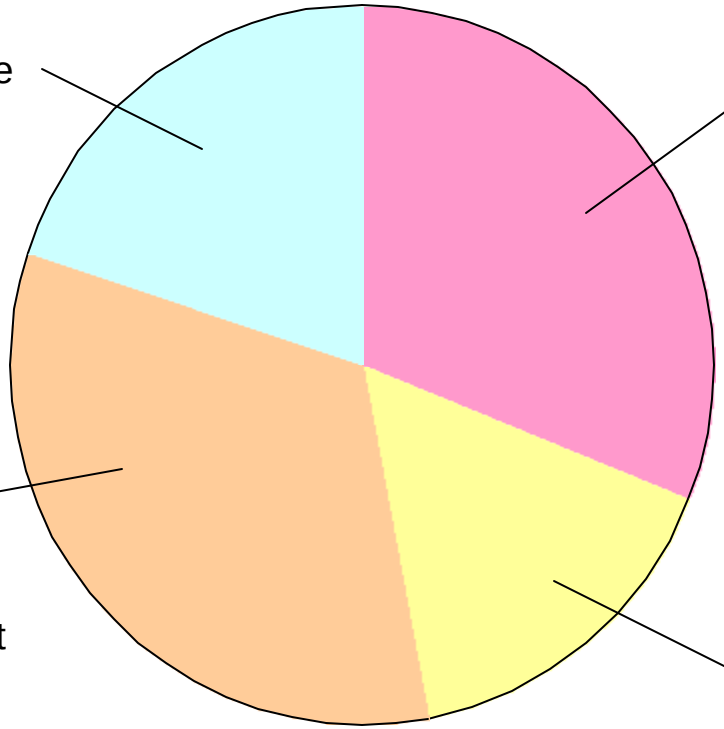


Effects of Technology Improvement

Future Transport Helicopter

Percent gross weight/cost reduction by source

1994-2005



Drive System: 20%
- Reduction ratios per stage
- Power-to-weight ratio
- Operating/overhaul cost

Aeromechanics: 31%
- Hover efficiency
- Propulsive efficiency
- Vehicle drag
- Predictive design tools
- Vibratory loads

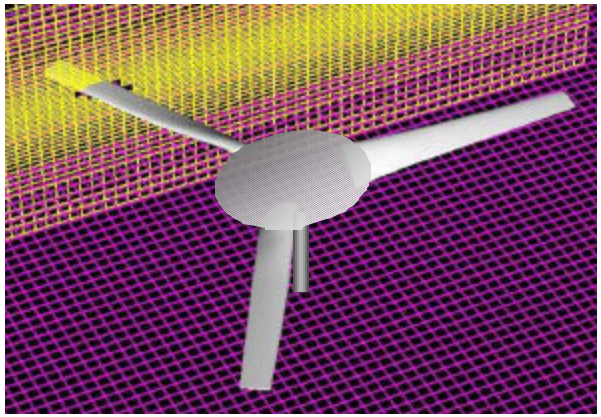
Engine: 33%
- Fuel consumption
- Contingency ratings
- Power-to-weight ratio
- Operating/overhaul cost

Structure: 16%
- Weight reduction
- Advanced materials
- Design optimization tools
- Manufacturing cost

Advanced Rotor/Drive System Concepts

Continuous control of shape and airflow achieves near-ideal performance

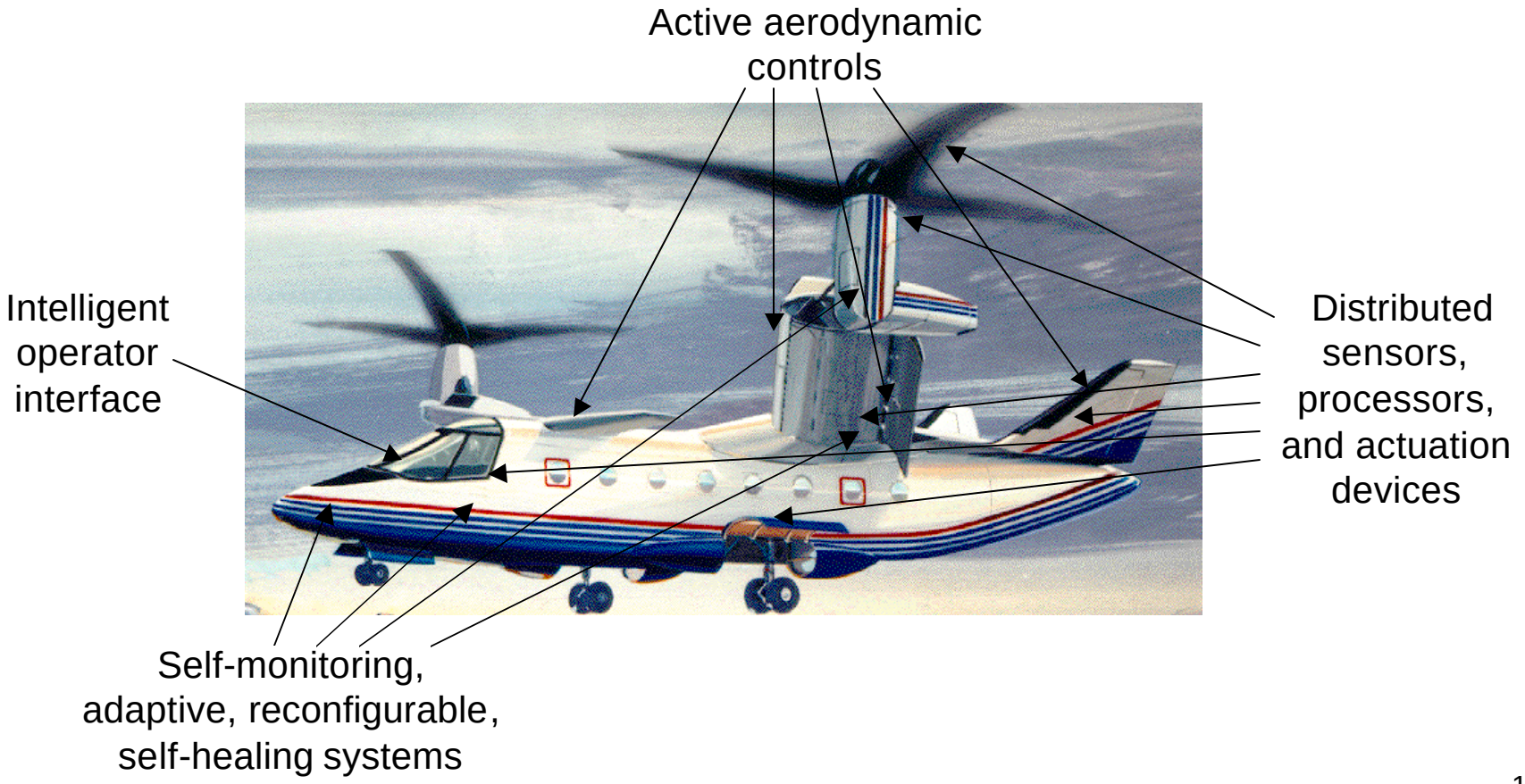
- Smart material "morphing" blade geometry
- Active blowing and boundary layer modification



- Swashplate-less control
- Active vibration and noise control
- Lightweight rotor construction
- Low-noise geometry
- Reverse velocity airfoils
- Super-safe rotor and drive shaft
- Variable speed, intelligent, self-reconfigurable drive system

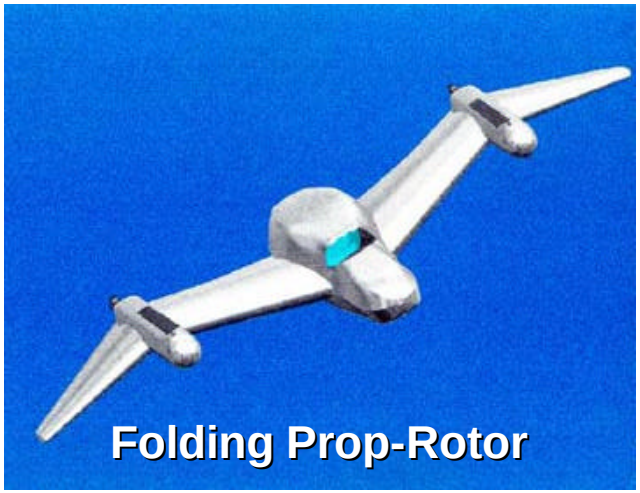
Bio-Analogous Distributed Systems

Distributed sensors, processors, and actuation devices tailor drag and lift, counter vibration, diagnose faults, and implement corrective action



Advanced Vehicle Configurations

High speed enhances productivity of piloted and uninhabited rotorcraft



Personal Transport "Crashproof" Rotorcraft

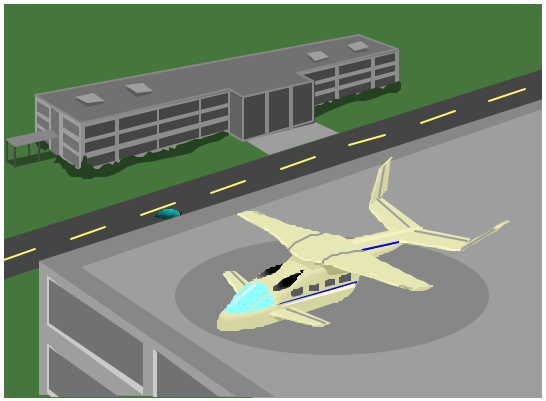
UAV technology and smart systems enhance safety and reliability

Environmentally friendly

- *Low-noise rotor*

Economical

- *Low-cost construction*
- *Affordable propulsion system*

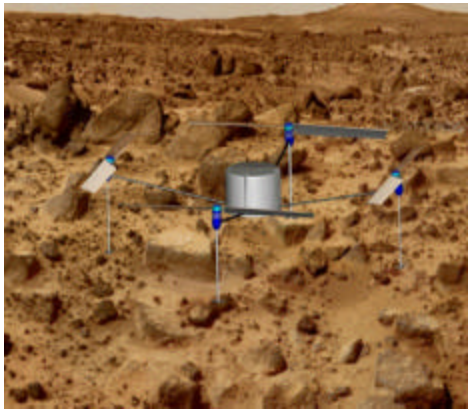


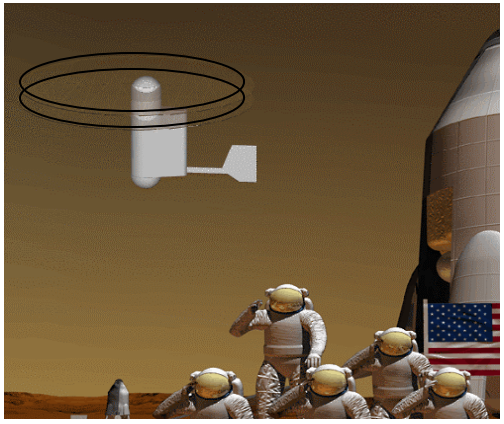
Safe and easy to operate

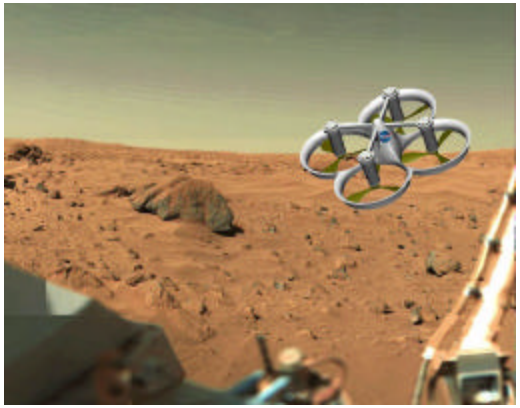
- *Smart autonomous self-reconfigurable control system*
- *Super-safe health & usage monitoring and advanced diagnostics*

UAV Technology Expands Rotorcraft Applications

Martian autonomous rotorcraft for scout and utility roles could hunt for water and search for life







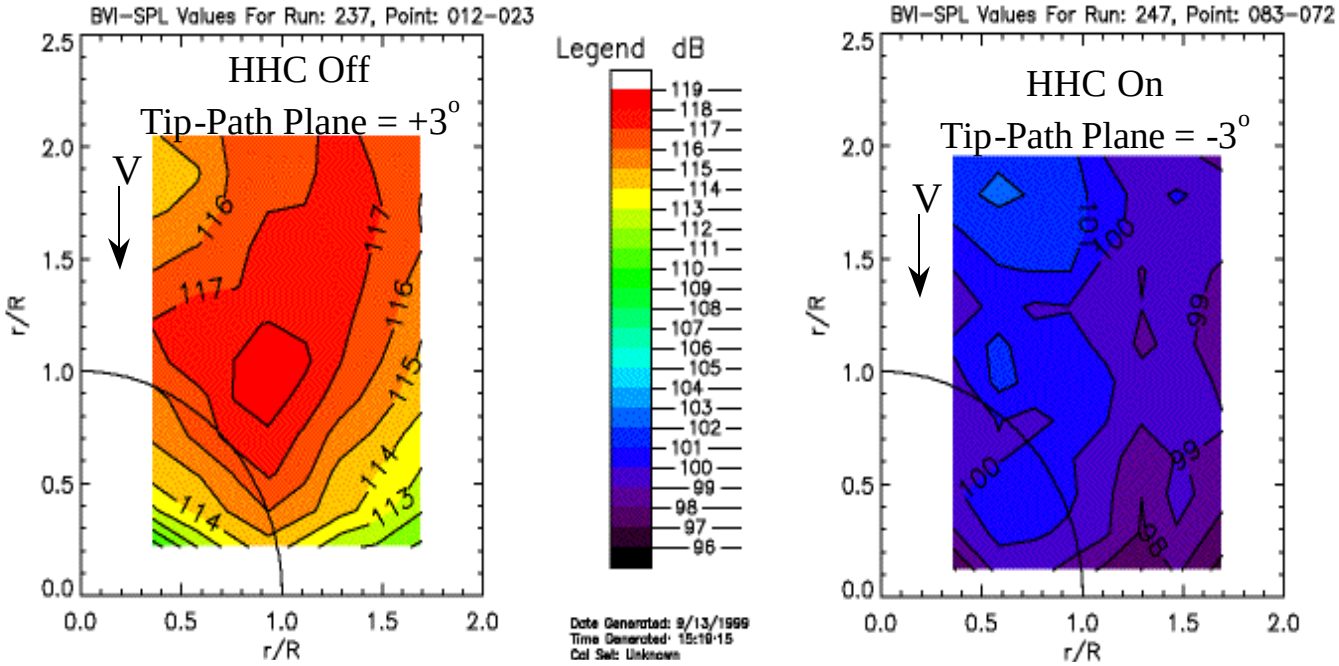
New Large Rotor Test Apparatus (LRTA)

On-line in 40 x 80 ft wind tunnel as of September 2000

- Helicopter/tilt rotor compatible
- Up to 50,000 lb thrust, 6,000 HP
- Steady/dynamic rotor balance
- Complete control system with primary and dynamic control

Tiltrotor Noise Reduction Breakthroughs

Typical reductions of 12.5 dB demonstrated in wind tunnel tests



XV-15 Low-noise Approach Profiles

RASCAL

Rotorcraft Aircrew Systems Concepts Airborne Laboratory

National In-Flight Simulation Facility
for Rotorcraft and VTOL Aircraft

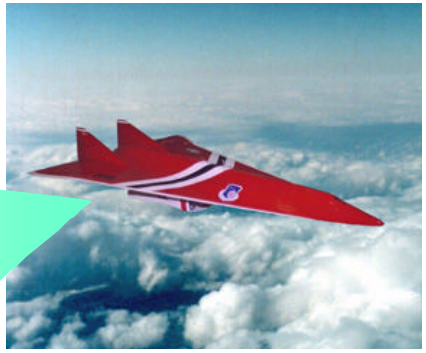
- programmable high bandwidth full authority flight control
- five degrees-of-freedom (programmable stabilator)
- high performance flight control processor with 160 channel analog i/o at 256 Hz and 4-channel 1553B
- evaluation pilot equipped with programmable active sidestick and programmable displays

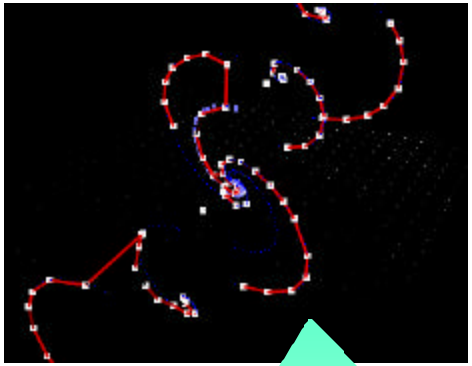
Smart Flight Control Systems Technology

Goals:

Increase Safety	*Automatically compensate for a broad spectrum of damage or failures*
Reduce Cost	*Eliminate expensive gain scheduling or explicit parameter identification*
Improve Efficiency	*Assist in rapid prototyping of aircraft designs*

Neural flight control will be applied to new aircraft designs





High performance neural network algorithms

Neural flight control tested on modified F-15 ACTIVE aircraft

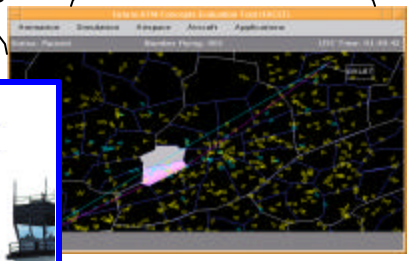
Neural flight control is being evaluated on a commercial transport simulator under nominal and failure conditions

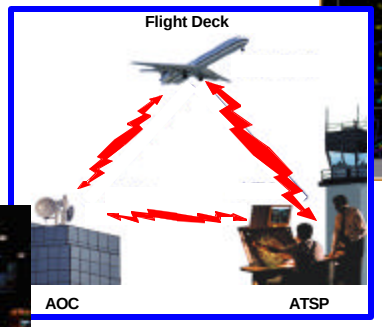
AvSTAR
(Aviation Systems Technology Advanced Research)

Enabling Tomorrow's Air Transportation System

Improved traffic flow management

Remove restrictions across facility/sector boundaries





National Traffic Flow Management

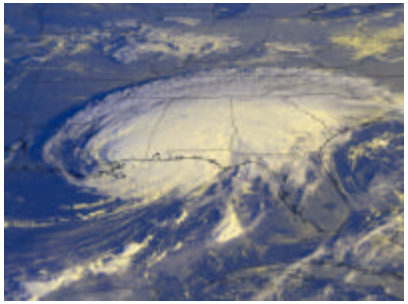
Reduce separation in the terminal area

Integrated Airspace Decision Support Tools

Eliminate surface congestion

Arrival/Departure Decision Support Tools

Runway Productivity



ATM/TFM Weather Integration

Surface Congestion Alleviation

Runway Independent Aircraft Operations

AvSTAR

Runway Independent Aircraft Operations

Objectives:

- **Develop technologies & criteria database that will:**
  - **Enable simultaneous non-interfering (SNI) A/C ops**
  - **Allow V/STOL aircraft to operate at airports under Cat IIIA**
  - **Establish ops requirements for future powered lift A/C**

Benefits:

- **Air traffic growth without enlarging airports**
- **Aviation System throughput increase & delay reduction**
- **Airspace safety & reliability improvement**
  - **Vehicles use unused & underutilized space**
- **National mobility & accessibility increased**

Activities:

- **SNI Criteria Database Development**
  - **Ops Concept**
  - **Adverse weather / low noise ops**
- **ATM / Aircraft Systems Integration**
  - **Human Centered Cockpit**
  - **ATM tools**
- **V/STOL A/C Performance / Airspace Requirements Database**
- **Demonstrations**

Key Issues:

- **Air & and infrastructure requirements**
- **Level I handling qualities**
- **Non-interfering missed approaches & guided departures**
- **Low noise flight paths**
- **SNI ops concept acceptance**

Summary

- Rotorcraft can play a vital role in both civil transportation and robust military systems of the future
- This vision can be realized only with major improvements in *cost, noise, all-weather reliability, and passenger acceptance*
- Active system technologies, information technology, and innovative configurations are key to improving these attributes
- NASA Ames activities are aimed at enabling both the infrastructure and the air vehicles of the future